LA-UR-19-26149
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Title: Collimated Beams for Cement Evaluation

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Intended for: Report

Issued: 2019-06-28

Collimated Beams for Cement Evaluation

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Chevron
27 Jun 2019

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Acoustics and Sensors Team

http://www.lanl.gov/orgs/mpa/mpa11/AcousticsAndSensorsTeam

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Well Integrity Monitoring
Acoustic Separation
CO_2 sequestration (DOE)
µarchitected Waveguides (LDRD-ECR)

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Research Technologist

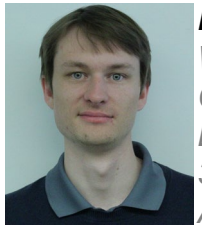
Mechanical and Electronics
Design, and System Configuration

John Greenhall

Postdoc

Machine Learning
3DHEAT
Defects in Thermoelectric Wafers
Welding inspection
Electronics design

Eric Davis



Postdoc

Well Integrity Monitoring
CO_2 sequestration (DOE)
D_2O content in heavy water
3DHEAT
Acoustic Monitoring of Pu
NDE of weapons components

Hung Doan

Postdoc

Corn stover acoustics sensor
Well Integrity Monitoring

Dipen Sinha

Visiting Scientist

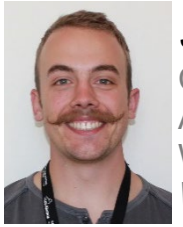
Defects detectionThermoel Wafers
Welding inspection
NDE of weapons components
Electronics design

Kai Gao

Postdoc

Well Integrity Monitoring
CO_2 sequestration (DOE)
Reverse time migration
3D inversion

Karl Niendorf



Summer GRA

COMSOL programming
Acoustic Tomography
Waveform inversion
Well Integrity Monitoring

Alan Graham

Research Associate

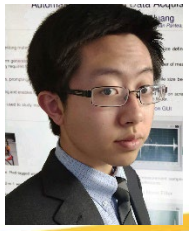
Defects detection in wafe
Welding inspection
NDE of weapons compor

TBD

Post-Master

Corn stover acoustics
Well Integrity

Sincheng Huang



Summer GRA

Instrumentation development
LabView programming
D_2O content in heavy water

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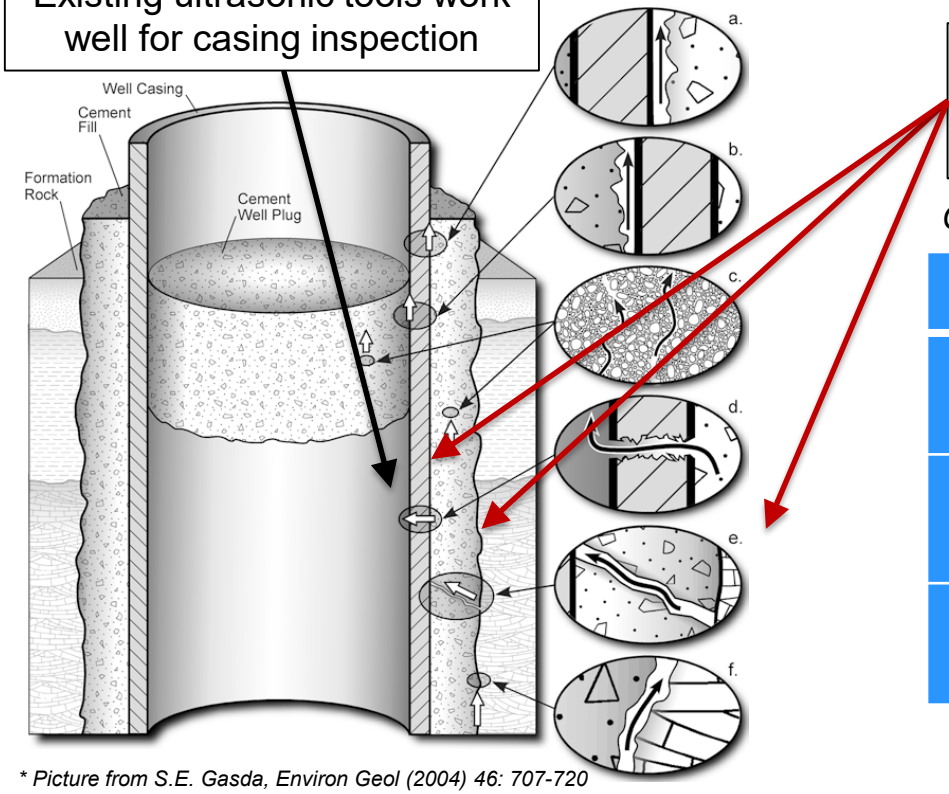
NNSA National Nuclear Security Administration

Los Alamos NATIONAL LABORATORY EST. 1943

Collimated Beams for Cement Evaluation

Existing ultrasonic tools work well for casing inspection



* Picture from S.E. Gasda, Environ Geol (2004) 46: 707-720

Extend applicability to: (1) casing-cement interface, (2) cement-formation interface, and (3) out in the formation (up to ~ 3 meters).

Comparison of existing techniques and the present approach

Method	Frequency (kHz)	Range (m)	Resolution (mm)
Sonic probe	0.3-8	15	~ 300
ACCObeam	10-250	~ 3	~ 5
Ultrasonic probe	>250	casing	4-5

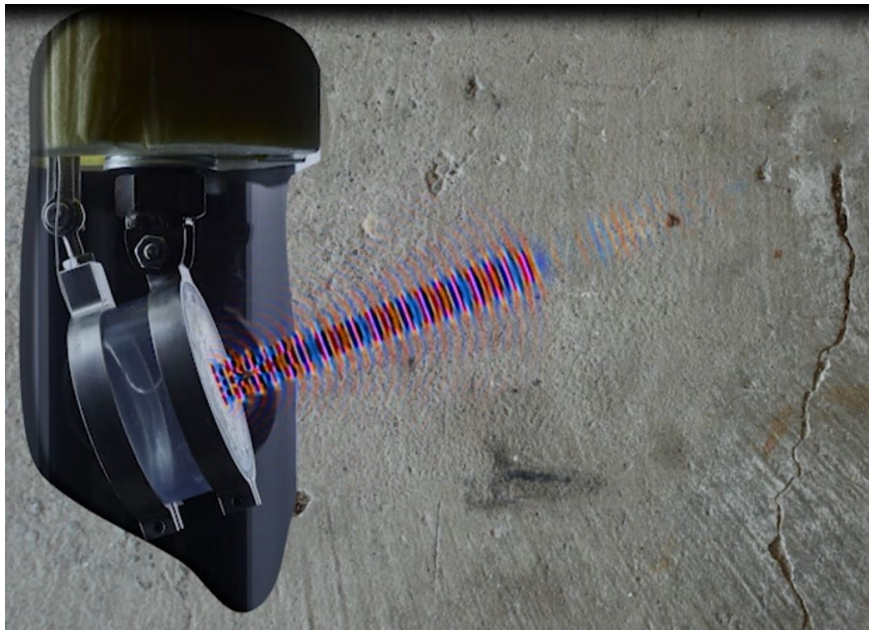
ACCObeam
Acoustic Collimated Beam

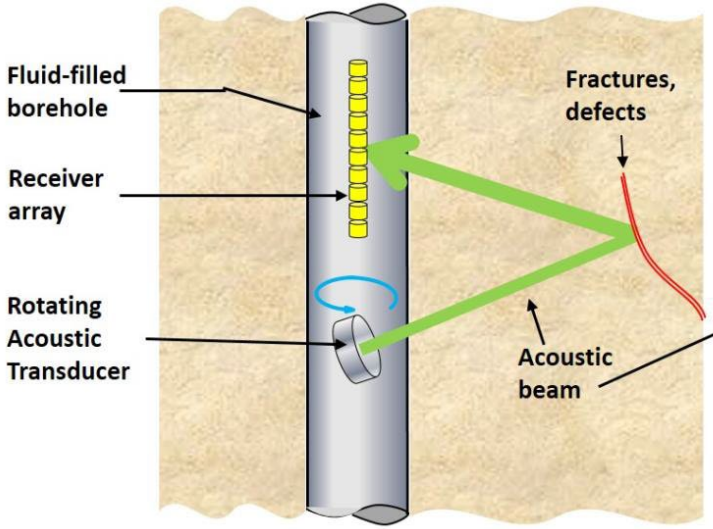
Novel sound beam:

High-power **Low-frequency** **Collimated**

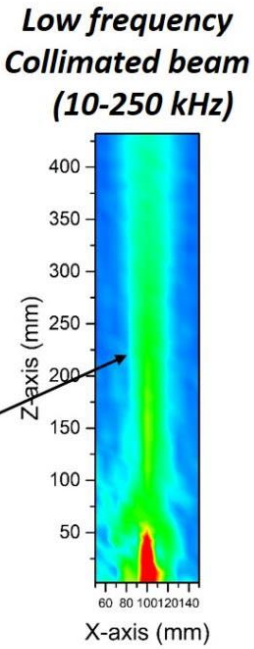
resulting in

Deeper penetration + High resolution





360 degree imaging



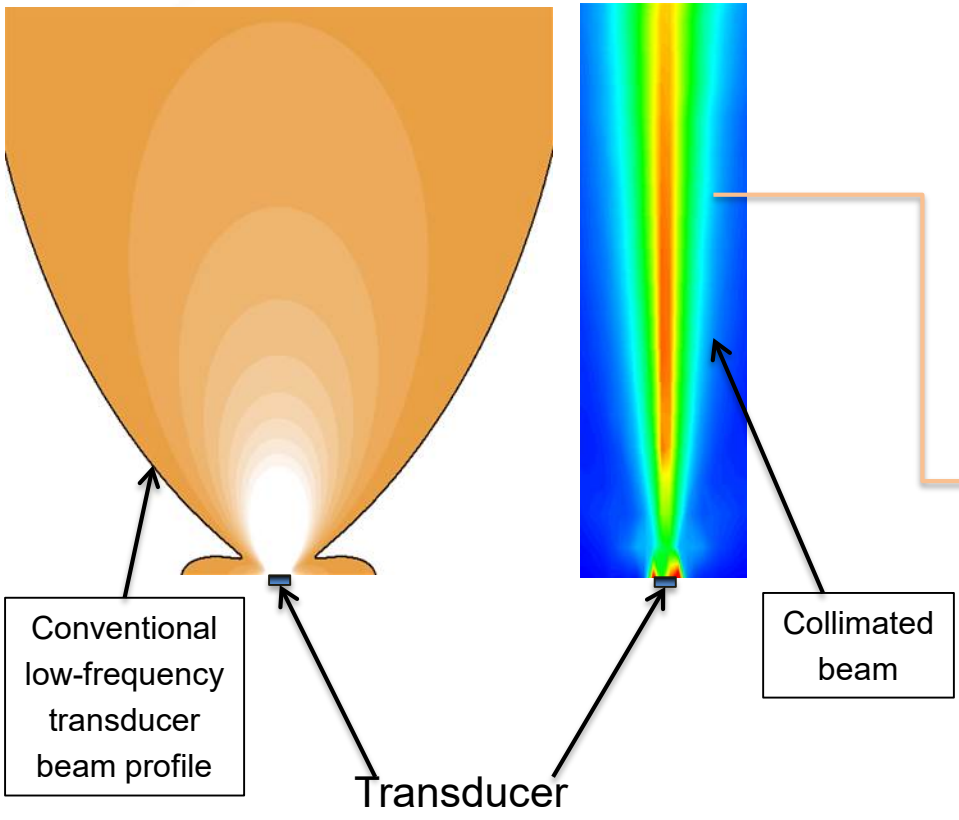
No side-lobes

Multiple areas of applications, e.g. borehole imaging, explosives threat evaluation, underwater communication, biomedical imaging.

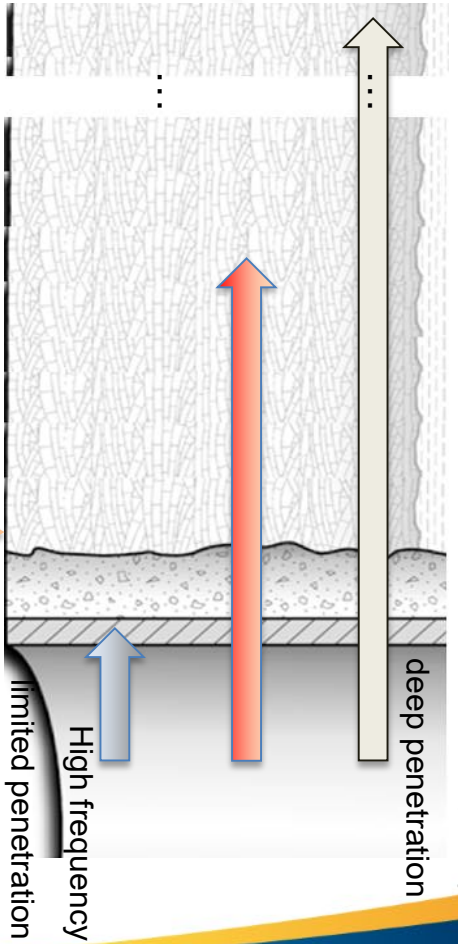
Proposed Approach:

Detect objects underwater,
using a low-frequency, collimated beam.

1. Collimated beam for increased resolution



2. Low frequency for deeper penetration



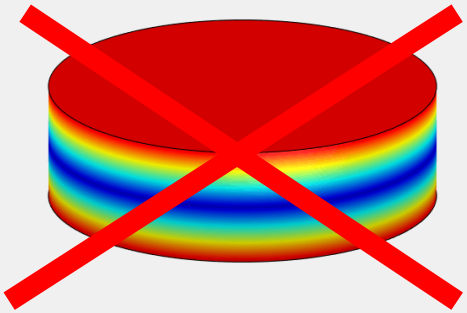
Attenuation ~ f^n

f = frequency, *n* = 1-2

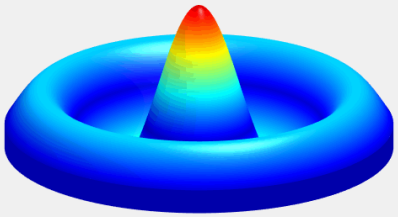
ACCObeam

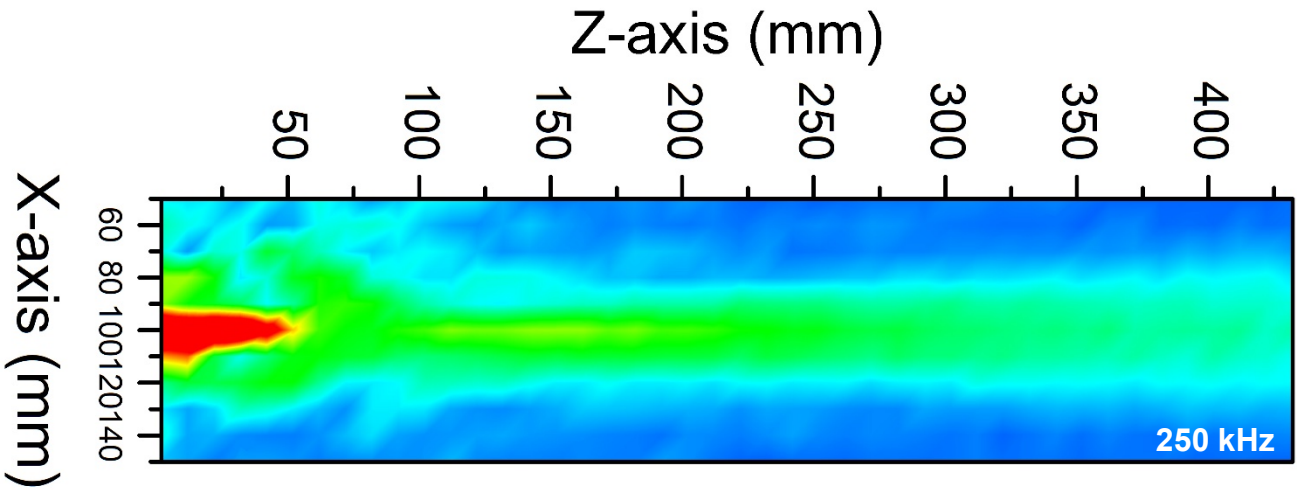
- **Bessel-like Acoustic Source**

Fundamental mode



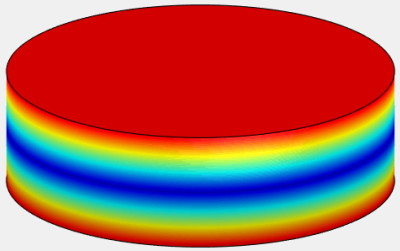
Radial mode



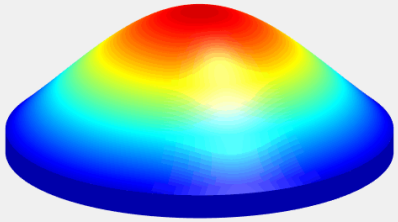


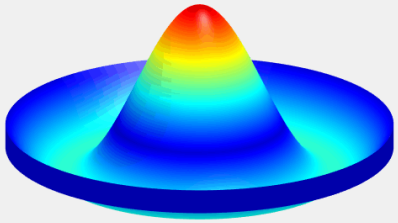
ACCObeam

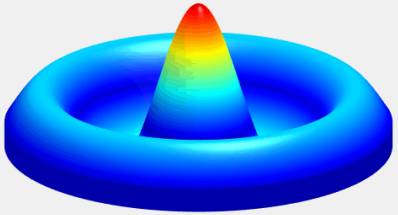
Fundamental mode

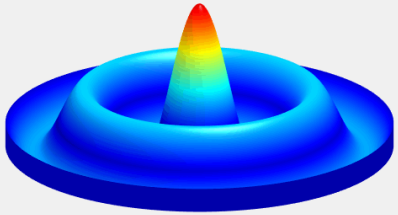


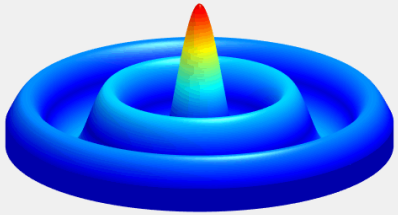
Radial modes





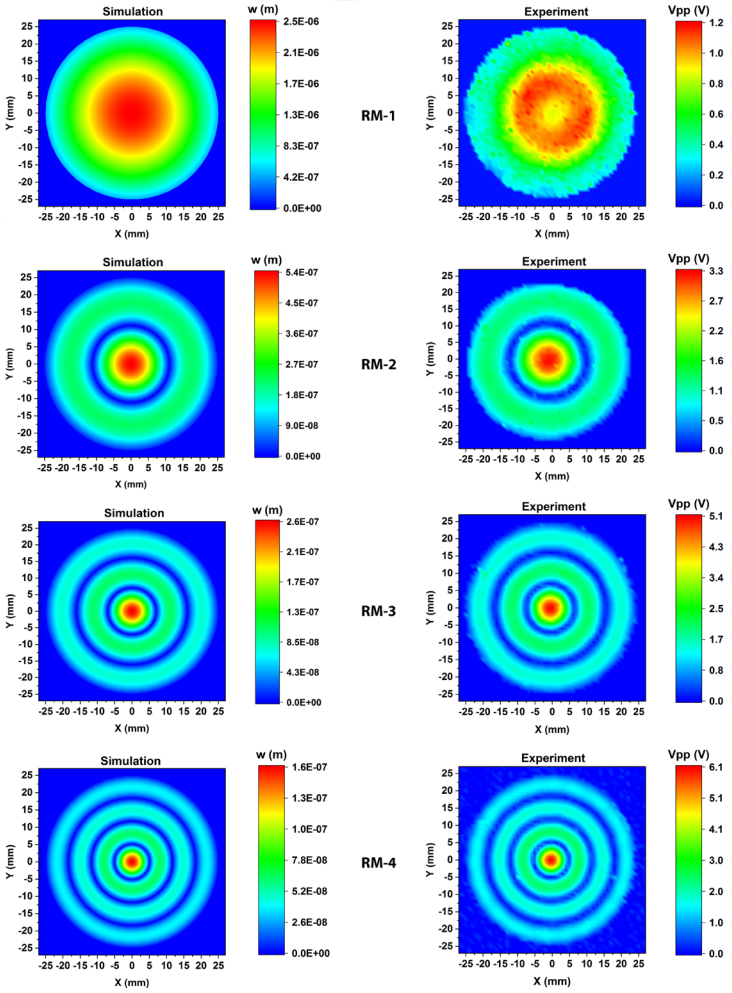




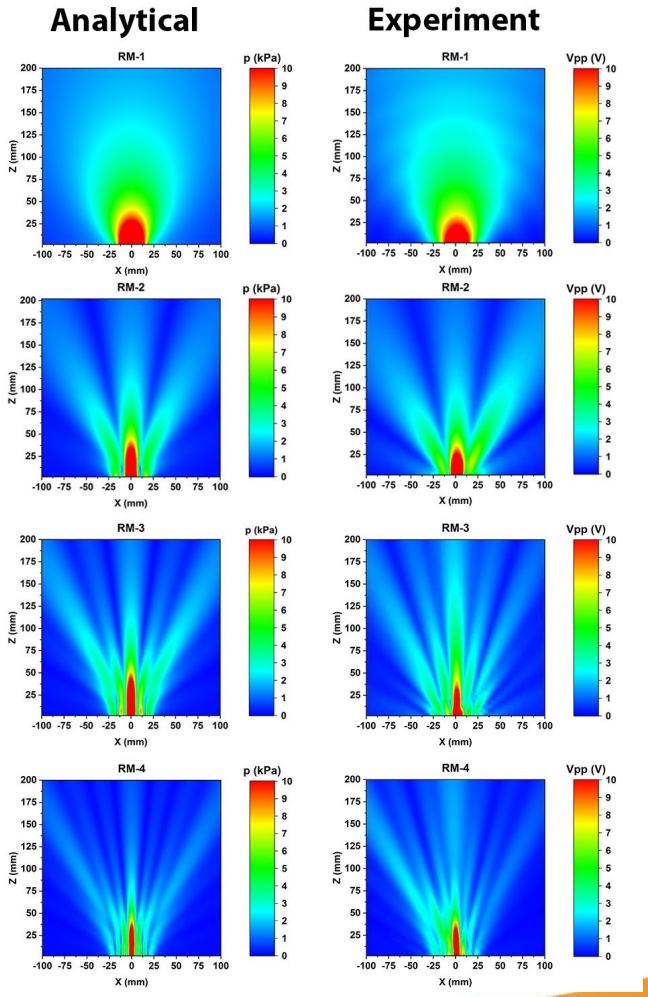


Radial Modes of Acoustic Transducer

Comparison of analytical and experimentally obtained out-of-plane displacement patterns of the radial modes

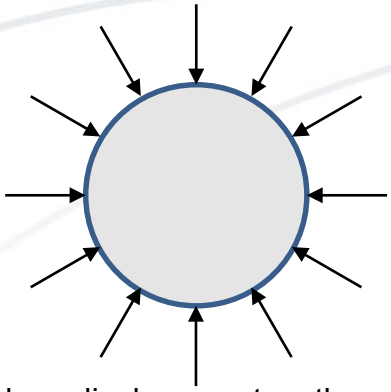


Comparison of analytical and experimentally obtained beam profiles from the radial modes

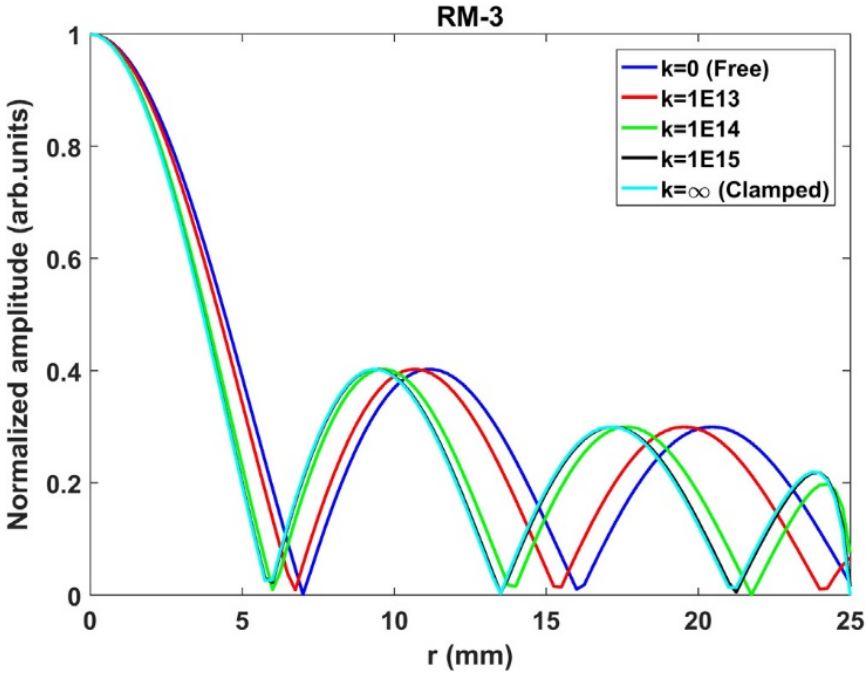


Paper recently submitted

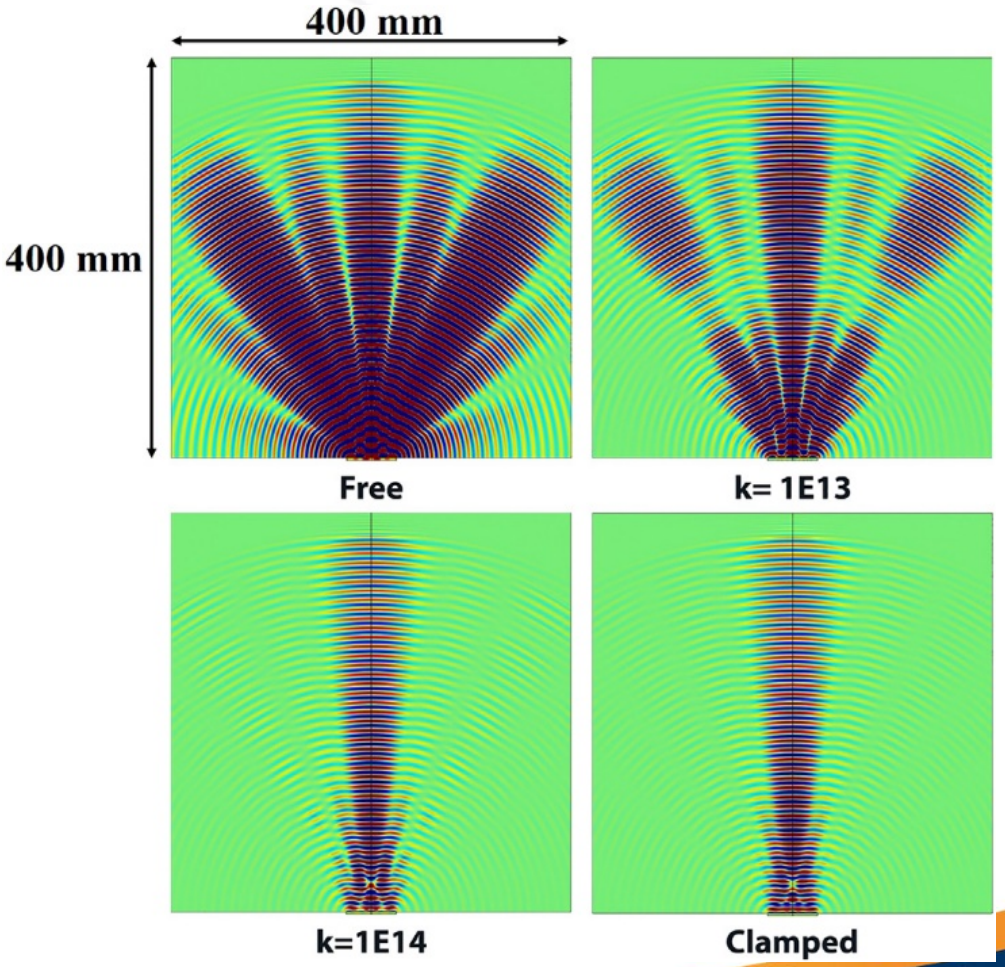
Radial Modes of Acoustic Transducer Clamping Effect



Normalized out-of-plane displacement on the surface of the disc for RM-3 for different lateral stiffness k (N/m3)



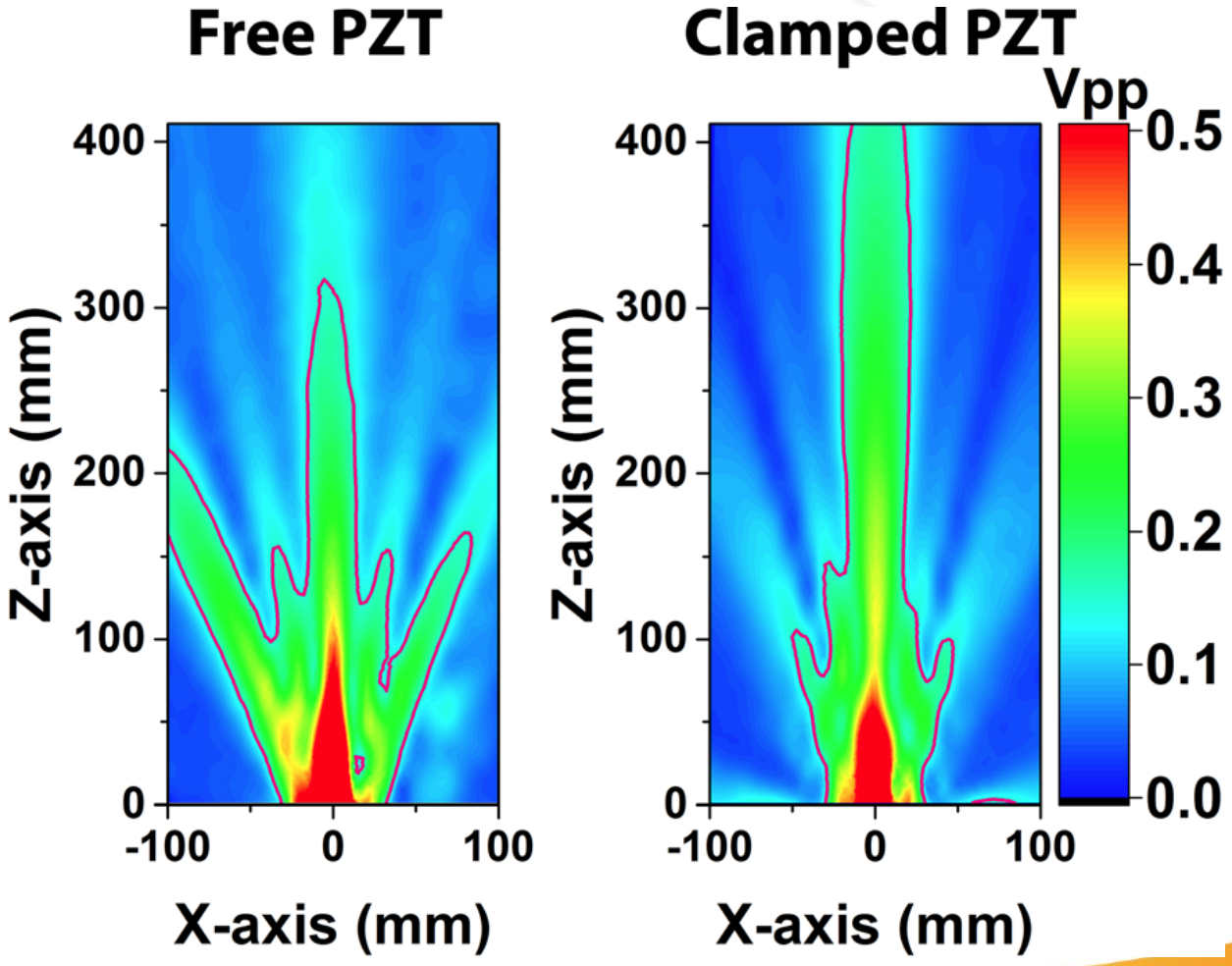
Ultrasonic beam profiles in water generated by RM-3 at 161.8 kHz for different lateral stiffness k



Wave Motion, vol. 76, (2018), pp. 19-27 and Proceedings of SPIE, vol. 10170, (2017), Article no. 1017024

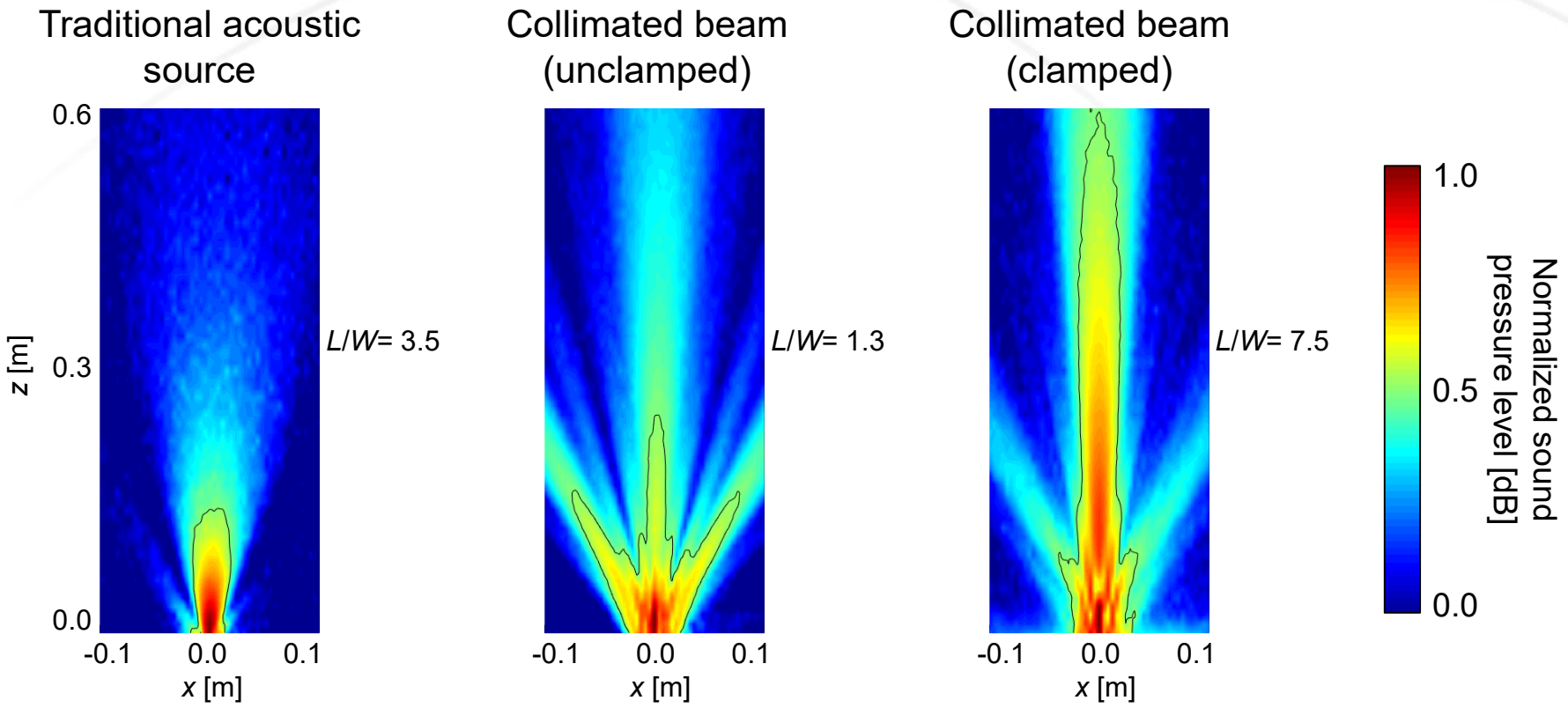
Clamping Effect – Experimental evidence

Beam profile in water for the 3rd radial mode RM-3;
free transducer (left) and clamped transducer (right)



Appl. Phys. Lett., vol. 110, issue 6, (2017), 064101

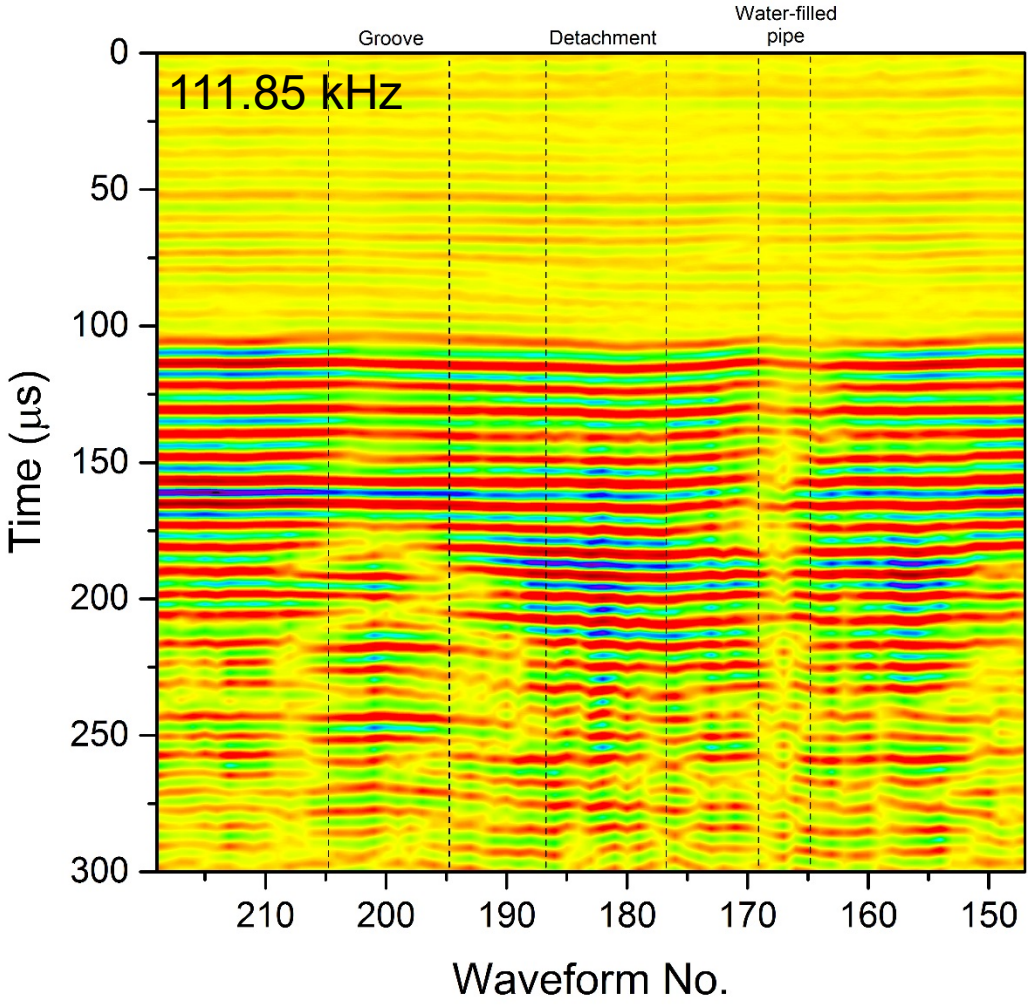
Clamping Effect – Experimental evidence



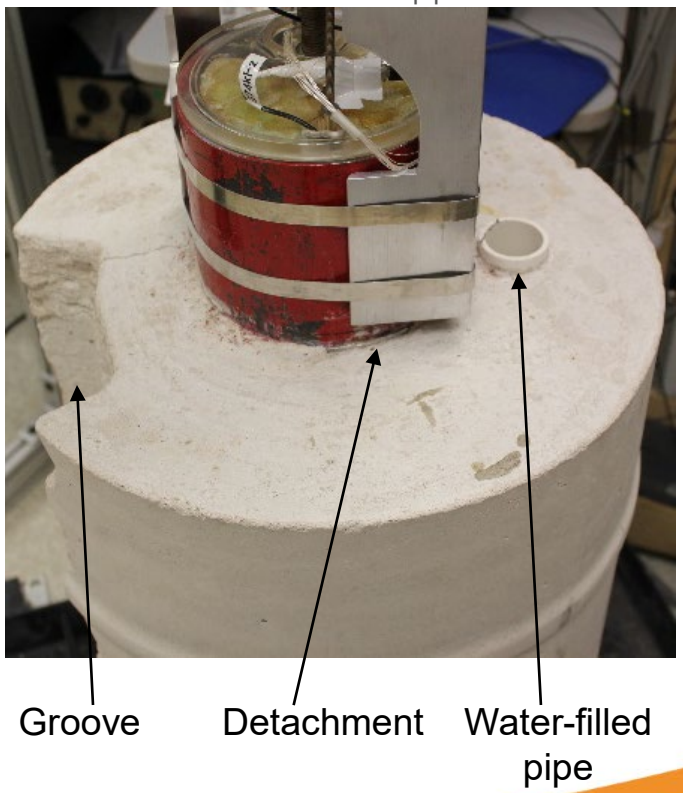
- Collimated beam provides:
  - Reduction in beam width → higher image resolution, more control over directivity
  - Increased beam length → longer detection range

ACCObeam - Defects detection

Cased borehole configuration (Steel-lined cement barrel)
Reflection seismology – Common receiver representation

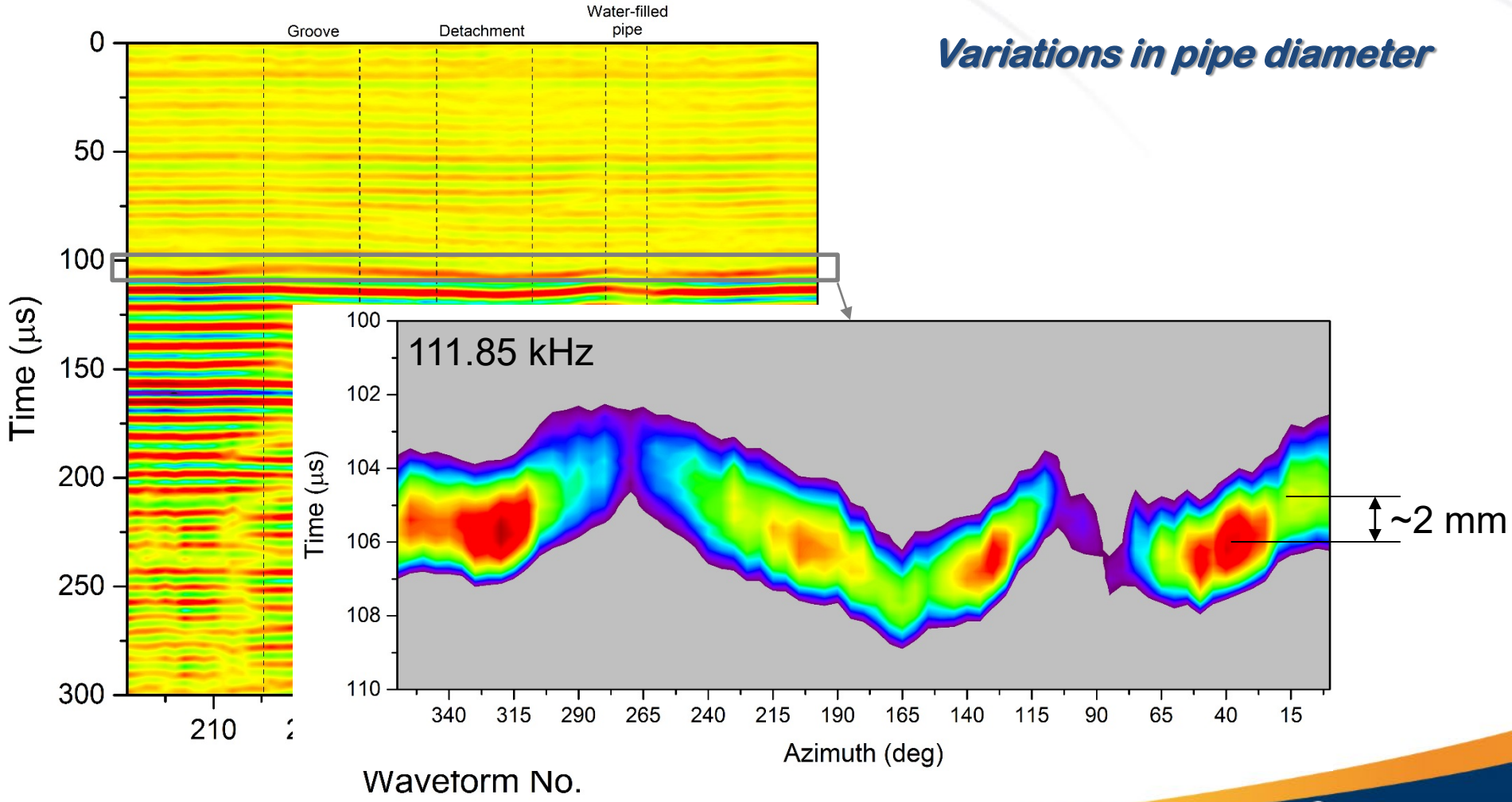


Cement OD: 460 mm
Cement ID:170 mm
Steel pipe ID: 148 mm
Steel pipe thickness: 10 mm
Groove depth: 50 mm
Plastic pipe location: 25 mm



ACCObeam - Defects detection

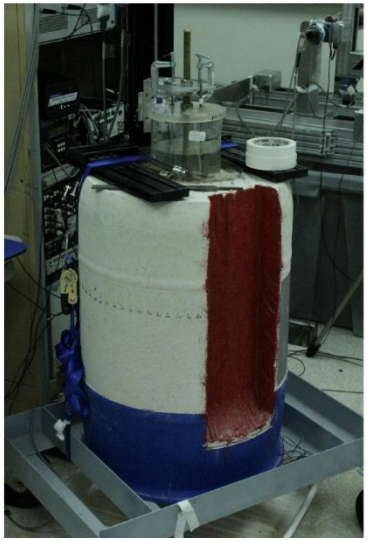
Steel casing barrel – Bessel-like Source

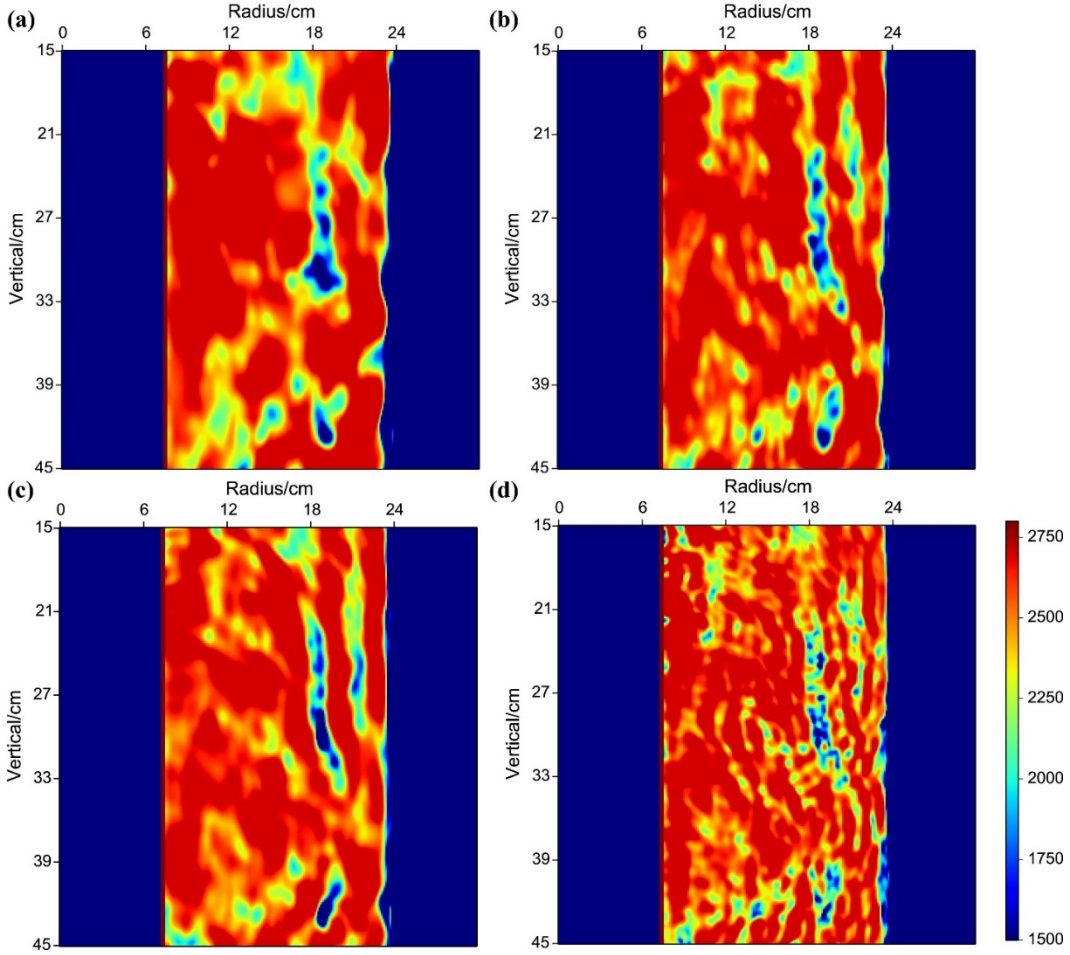


Variations in pipe diameter

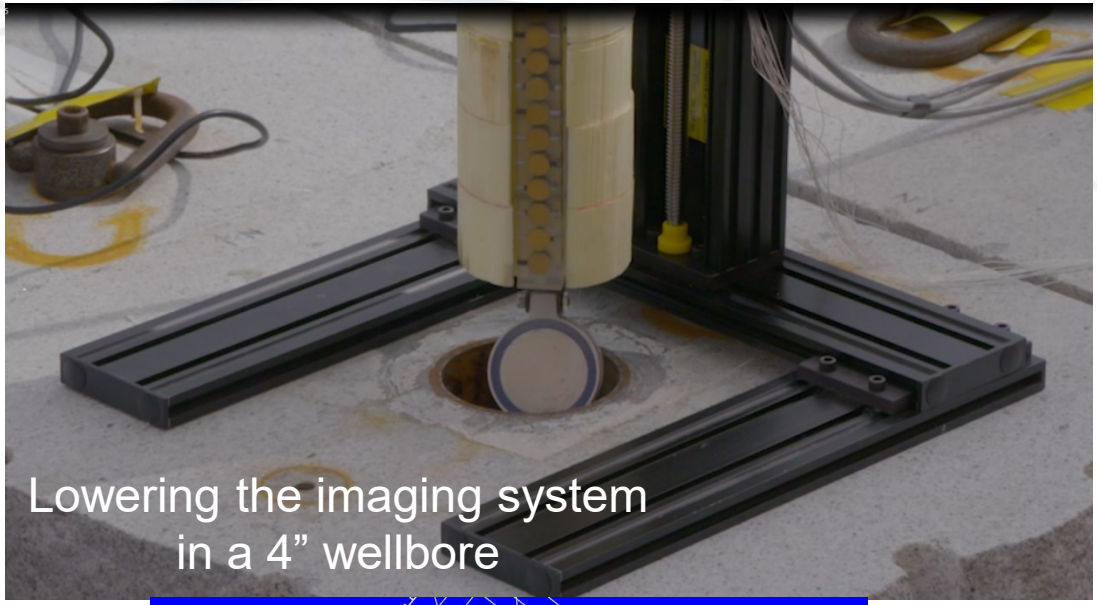
ACCObeam - Acoustic Inversion and Imaging

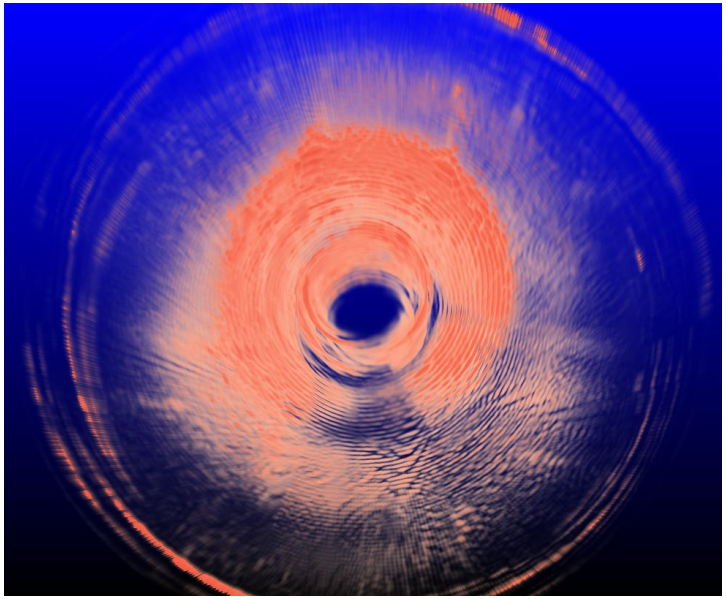
Velocity model for the long-radius profile from acoustic inversion using (a) 29 kHz data, (b) 42.4 kHz data, (c) 58 kHz data, and (d) 111.85 kHz data.

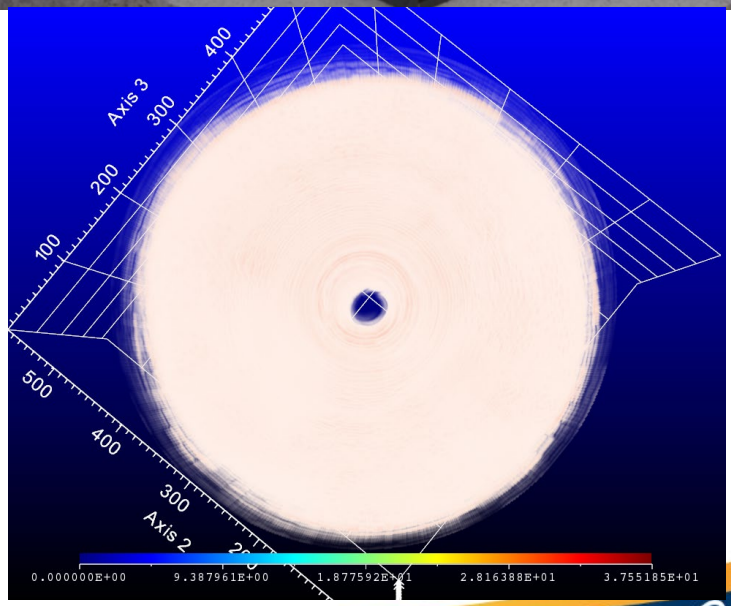




ACCObeam – Very Fresh Data. Work in progress





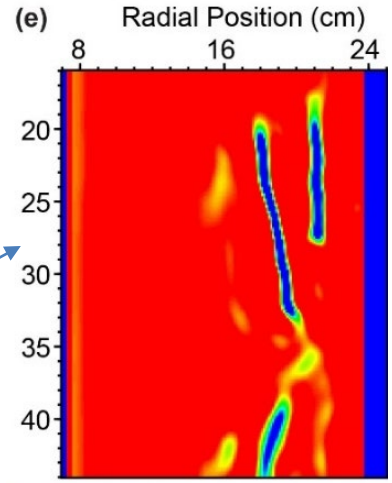


Well Integrity

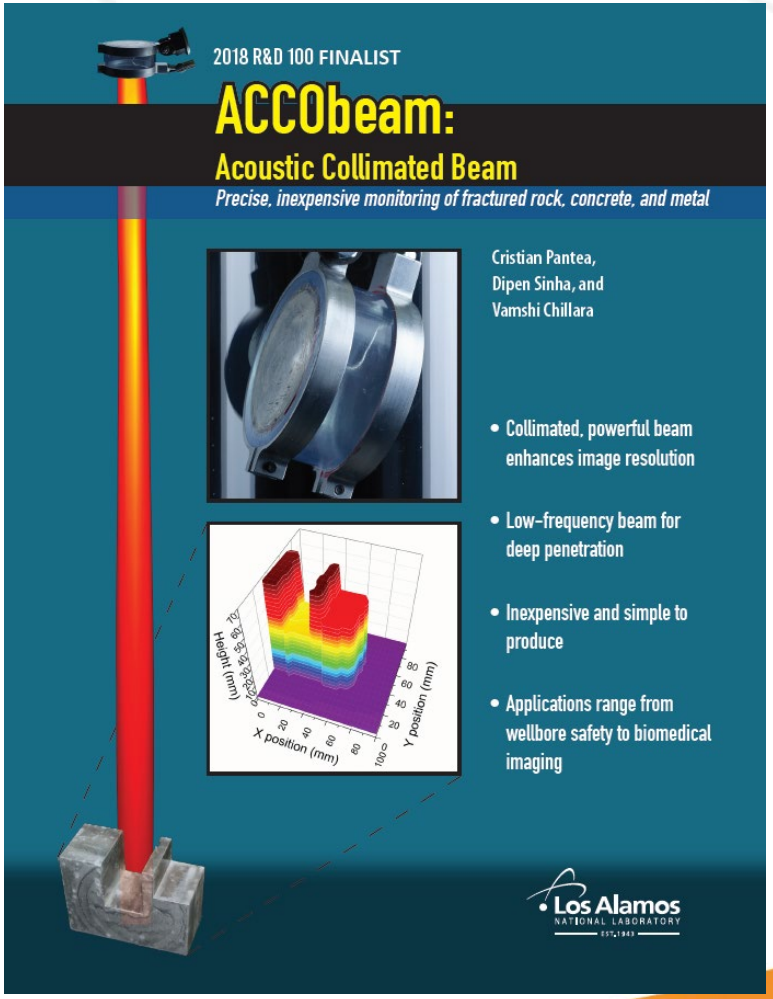
In subsurface applications, such as
Oil & Gas, Geothermal, Carbon Sequestration, Nuclear Repositories

Experimental concrete barrel with LANL's 3D imaging prototype in a borehole located at the center of the concrete barrel

Result of full-waveform inversion obtained using the center frequencies of 58 kHz



Vertical slice showing zones with heterogeneities. Illustrated is sound speed of 1.8 – 2.5 km/s



Summary

- No commercial acoustic sources that provide a collimated beam over a frequency range of 10–250 kHz in a small package that works in different media
- Recently improved acoustic source – ACCObeam: much more powerful than its predecessor (which was based on nonlinear acoustics)
- Demonstrated imaging capabilities of the system, in both open- and cased-borehole, for different induced defects (groove, detachment, fluid-filled void pocket, casing).
- Future R&D:
  - Refine and enhance the capabilities of the 3D imaging system for more realistic environments, and extended investigation range beyond the wellbore casing.
  - Identify new applications.

Low-Frequency Acoustic Collimated Beam
-Selected Publications-

- Ultrasonics, 2019, v. 96, issue 7, p. 140
- Appl. Phys. Lett., 2018, v. 113, issue 7, p. 071903
- Wave Motion, 2018, vol. 76, p. 19-27
- Appl. Phys. Lett., 2017, v. 110, issue 6, p. 064101
- Proceedings of SPIE, 2017, v. 10170, p. 1017024

- 1 patent application(Resonance-based Nonlinear Source)
- 1 patent application (Bessel-like Acoustic Source)
- 1 provisional patent (Imaging Technique with Low-frequency Beam)